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Ellalee, Haider and Alali, Walid Y.

Oxford Institute for Economic Studies, Oxenford House, 13-15 Magdalen St, Oxford OX1 3AE, UK, University of Oxford – Economic Department, Manor Road Building, OX1 3UQ, Oxford, UK

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Haider Ellalee

Oxford Institute for Economic Studies, Oxenford House, 13-15 Magdalen St, Oxford OX1 3AE, UK

Walid Y Alali

University of Oxford – Economic Department, Manor Road Building, OX1 3UQ, Oxford, UK

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Abstract: *The objective of this research is to find the preferable carbon taxation regime to achieve net-zero carbon emissions and enhance social welfare levels. Two regimes were discussed in this paper, including a carbon tax at the aggregate level of social welfare (CTTW) and a carbon tax at the level of single social welfare (CTSW). The results present a preferable regime depending on the substitution of the product and product price flexibility of demand. Not only does industrial transformation bring about changes in the substitution of the product and demand flexibility in product prices, but as well both regimes have a serious effect on achieving net zero carbon emissions and enhancing the level of social welfare.*

Keywords*: Social welfare, Carbon Tax, Carbon Emission, Environment*

1 Introduction

The International Panel on Climate Change (IPCC) states that climate change will not stop if net zero emissions are not achieved. Net zero carbon emissions mean that net carbon dioxide (CO2) emissions must be reduced to zero in order to stabilise global temperatures. The Paris Agreement set the goal of net zero carbon emissions by 2050. Generally speaking, a carbon tax is one of the different methods available to achieve this goal.

It is widely known that a carbon tax can effectively eliminate environmental externalities to mitigate global warming and climate change. The Pigovian tax, named after the English economist Arthur Cecil Pigou, is a popular theory of correcting for negative externalities. Baumol [1] systematically collects and arranges Pigou's works on modern economics. Based on the views of Borzuei et al. [2] and Mousavian et al. [3], the tax effects of the Pigouvian reduce the damage to the environment and increase the level of social welfare.

Information provided by the Energy and Climate Intelligence Unit [4] shows that a total of 127 countries have enacted a net zero carbon emissions strategy. Moreover, many global companies have formed a team "going to net zero", including Microsoft, Apple, Nike, Starbucks, Mercedes-Benz, etc., to jointly achieve the goal of net zero carbon emissions. Government carbon tax policy and corporate voluntary actions can strongly support achieving net zero carbon emissions. However, government policy, such as imposing a corporate carbon tax, will influence the behaviour of producers and consumers.

Tax shift is one of the impacts of tax collection. The effect of the tax shift could trigger the authority's carbon tax on the product and increase the tax burden on consumers. One wonders whether the effect of tax shift weakens the firm's motivation to engage in product differentiation and thus becomes an obstacle to industrial transformation in the direction of 'going to net zero'.

The EU officially announced the Carbon Limits Adjustment Mechanism (CBAM) in July 2021. The CBAM imposes a carbon tax on high-carbon products by offsetting the carbon price between domestic products and imports to ensure that the EU's climate goals are met. The European Union has confirmed that carbon tax revenues will be used to promote decarbonisation technology. Therefore, this paper compares different carbon tax regimes and their effects on the achievement of the goal of net zero emissions and the promotion of the level of social welfare (SW).

There are two regimes of the carbon tax in this study: The first one is a carbon tax at the Single Social Welfare Level (CTSW), which indicates that CBAM specifically addresses carbon emissions. The other is a carbon tax at the Total Social Welfare Level (CTTW). This study investigates finding the best carbon tax regime to achieve the goal of net zero emissions.

Definitions

CTSW	Single Social Welfare Level
CTTW	Total Social Welfare Level
SW	Welfare Level
SWL	Social Welfare Level
NZC	Net Zero Carbon
NZE	Net Zero Emissions

2 Literature review

Environmental economics is concerned with the effect of externalities on social well-being and how these externalities can be removed to achieve the environmental goal and maximise social well-being. With the onset of net zero carbon emissions, a carbon tax is seen as one of the most powerful tools to help countries reduce carbon emissions and reach zero net targets. Early studies discuss a tax in environmental economics through environmental taxation, but environmental tax research has shifted to a carbon tax in the direction of net zero carbon emissions.

Tax affects not only market competition but also social welfare. Shaffer [5] and Lee [6] impact investigated an environmental tax in oligopolistic markets, and Garcia et al. [7] and Lyall et al. [8] analysed the effects of environmental taxes on the company's activity and the level of social welfare. Liu et al. [9] discovered that the tax on carbon impacts social welfare negatively. However, tax shifting is critical when the government puts pressure on tax policy. The tax on carbon is used by the government for controlling the pollution behaviour of the company. Anand and Giraud-Carrier [10] suggest consideration for imposing the tax (environmental tax) not on firms but on consumers because firms may collude the government tax regulations by reducing production (at the same time, the pollution) to improve their profits. We would expect that if the tax on the environment causes corporate complicity or shifts a tax imposed on producers onto consumers, the consumer surplus will be damaged by this tax, therefore social welfare will not be maximised.

The tax shift magnitude is very close to the price elasticity of the demand for the product. Wang et al. [11] found out that the elasticity of the price of demand in the cement market in China is so great that the tax on the environment imposed on the cement industry shows, a negative impact on corporate revenue and profits. Kotl'an et al. [12] examine the Green Deal of the European and conclude a high tax on the environment affects negatively economic activities and limits sustainable development policy implementation. Mousavian and others. [3] Indicate that the carbon tax reduces energy consumption and emissions of pollutants, while it can also show an impulse to create new jobs by decreasing the employment tax. Hence, the effect of tax generates a systemic effect on many economic levels. Different from the tax on the environment, a carbon tax's purpose is to strip greenhouse gas emissions (GHG) by accommodating the externalities that cause GHG emissions. Wang et al. [13] classified the functions of the environmental tax and carbon tax mentioned in their study, as a carbon tax set to reduce carbon emissions and an environmental tax to reduce air pollutants. Carbon Tax could help global warming stabilise and prevent climate change. Quarton and Samsatli [15] and Pradhan et al. [14] discuss net zero emissions of carbon from the tax on carbon point of view. Studies In academic circles have different directions on the carbon tax, such as Bachos et al. [16] study the impact of the carbon tax mandated on energy products. The model of Ouchida and Goto [17] product manufacturing process tax, while Nie et al. [18] Discussion of tax on carbon in a monopolistic market. In the exercise, Millot et al. [19] mention that France applied a tax on carbon in 2014 of €7/tCO_2 rate in the Green Growth Energy Transition Act and to reach €100/tCO_2 in the year 2030.

Achieving the goal of net carbon emissions, the low-carbon economy of industrial transformation is a path, and one of the nice tools is a carbon tax. Manufacturing is rarely discussed in the literature on carbon tax analysis, however, we find that many studies focus on the impact of a carbon tax on industry, for example, Cheng et al. [20] on supply chain and Liu et al. [9] On industrial power structure, Nelson et al. [21] on energy and emissions-intensive industries. The impact of the tax on carbon on industry development is important, while the more important issue is to effectively promote industrial transformation. The impact of social welfare consumer surplus, carbon emissions, and producer surplus can be understood by observing the manufacturing process.

The fields of the environment are impacted comprehensively by a Carbon tax, emission reduction, corporate market competition, consumer welfare, and industrial transformation. To check the impact of the carbon tax, two systems of carbon taxes are compared and investigated which include a carbon tax at a single welfare level and a carbon tax at an aggregate social welfare level. The first takes net zero carbon emissions as the main goal and then increases the level of social welfare. The latter not only takes into account the achievement of the net carbon emission target but also the maximisation of the level of social welfare.

3 Model Setup

We take into account a duopoly market of two producing firms with differentiated products. We pursue Singh and Vives's [22] view by providing a linear function of demand in a duopoly market which is different as follows:

$$p_1 = a - bq_1 - rq_2 \; and \; p_2 = abq_2 - rq_1 \tag{1}$$

Where a is the market size. Based on the two firms' linear functions in Eq. (1), the absolute value of demand elasticity of the product price is $| \; e_p^d \; | = 1/b$, where b is the demand function slope. The product cross elasticity of demand is $e_p^d = -1/r$, where parameter $r \in (0,1)$ denotes the product substitute between q_1 and q_2. Here, $r = 1$ ($r = 0$) means that q_1 and q_2 are perfect (independent) substitutes. According to the linear demand functions for the two firms, CS (consumer surplus) used to measure the benefits of the consumer benefits is:

$$CS = (1/2)(bq_1^2 + bq_2^2 - 2rq_1q_2) \tag{2}$$

Products during the production process have by-products. therefore, it is assumed each unit of output causes a unit of carbon emissions in our model analysis. After setting the quadratic model on the environmental damage (ED) function by Buccella et al. [23] One unit of the product causes one unit of carbon emissions, we have the ecological damage function as follows:

$$ED = (g/2)(q_1 + q_2)^2 \tag{3}$$

where the parameter $g > 0$ denotes the carbon emission factor of the product.

Based on the consideration of net zero carbon emissions, the authority imposes a carbon tax on products; Hence, the carbon tax burdens of the two companies are $T_1 = (t/2)q_1^2 \; and \; T_2 = (t/2)q_2^2$, since the carbon tax revenue of the authority is also a quadratic form similar to that of the environmental damage function. Since the authority uses the carbon emission tax revenue to remove the environmental damage caused by carbon emissions, we have $T = T_1 + T_2 = ED$. The profit of the company comes from its revenue minus the carbon tax burden, so the profit functions of the two companies are:

$$\pi_1 = p_1 q_1 - (t/2)q_1^2 \quad and \quad \pi_2 = p_2 q_2 - (t/2)q_2^2 \tag{4}$$

PS (producer surplus) is used to measure the firms' sum profits as follows:

$$PS = \pi_1 + \pi_2 = p_1 q_1 + p_2 q_2 - (t/2)q_2^2 \tag{5}$$

Since the level of social welfare (W) is measured by the accumulation of producer surplus, consumer surplus, environmental damage, and carbon tax revenue by the government, it is presented as follows:

$$W = CS + PS + T - ED = \left(\frac{1}{2}\right)(bq_1^2 + bq_2^2 - 2rq_1q_2) + p_1 q_1 + p_2 q_2 - (\tfrac{g}{2})(q_1 + q_2) \tag{6}$$

Where consumer surplus, carbon tax revenue and producer surplus provide positive reinforcement to the level of social welfare, environmental damage impact negatively on the same level. One may refer in general to Buccella et al. [23], Lambertini et al. [24], and Xu et al. [25] for the welfare formula in Eq. (6). When we think holistically about consumer surplus, producer surplus, and carbon tax, and the Damage in the environment in the function of the social welfare Damage, we find that optimal product quantity affects not only a measure of social welfare, but also measures of consumer surplus, producer surplus, carbon tax, and environmental damage. The optimal quantity has a connection to consumer surplus and producer surplus.

In more detail, if the product's environmental damage is large (small), then the optimal quantity is less (more), which deteriorates (enhances) consumer surplus and producer surplus.

The other point is about determining the SWF (social welfare function) shown in equation (6) Needs clarification on the relationship between environmental damage and carbon tax. The first is the social cost of treatment, and the second is the social welfare loss. The social welfare Environmental damage depends on the total quantity of the product and the marginal environmental damage for each product. In order to fix the environmental damage which affects by the manufacture of the product, the government always imposes a manufacturer tax. A Pigouvian tax is used to fix negative externalities caused by the market's activity, which means a tax rate equals the marginal environmental damage of the product. The Pigouvian tax concept of environmental damage could use the social welfare cost to communicate. Regarding this topic, return to the Eichner and Pethig literature [26], Fullerton [27], and Metcalf [28].

In the model, the competitive behaviour of two firms and authority action have described a game as a two-stage. In stage one authority defines the rate of the imposed carbon tax on them, while in stage two, the firms act quantitatively in competition. We obtain SPNE (subgame perfect Nash equilibrium) solutions by an approach of backward induction in which we fix the solution for the second stage after that a solution for the first stage.

In the game solutions of the two-stage, we obtain an individual firm's reaction function, as a profit function derivative concerning the product quantity. Next, using interaction functions as simultaneous equations to obtain the two firms' output quantities. Here, the company's output amount is as yet a carbon tax function. Since the full information of the two companies on the production quantities is available to the government, it can determine the carbon tax optimal to reduce the emission of carbon dioxide to a minimum, which is generated from manufacturing these products and achieving maximum social welfare. Finally, taking the government's optimal carbon tax by substituting with the production amount of the company to get optimal both company profit and production quantity.

4 Analyses of the Model

Here we compare two regimes by which a carbon tax at the social welfare single level considers the first regime, while the carbon tax at the overall social welfare level considers the second regime.

4.1 CTSW Carbon tax

In this regime, authorities chose a carbon tax emission (CTE) to clean environmental damage from carbon emissions before maximising the level of social welfare. According to equation (4), the two firms increase their profits in stage two, and we get the solution as $q_1 = q_2 = a/(r + 2b + t)$. To get the optimal rate of the carbon tax, we substitute solution $q_1 = q_2 = a/(r + 2b + t)$in stage two into equation (6), then the authority maximises the function of the social welfare subject to $T = ED$. Constraint $T = ED$ means achieving the target of NZC (net zero carbon) emissions by using the revenues of the carbon tax to evict all environmental damage that is impacted by carbon emissions. Then, the thematic function of this regime is $W = CS + PS + T - ED$ but subject to $T = ED$. Based on this approach of Lagrange, in stage one, the optimal solution is:

$$t^* = 2g \tag{7}$$

Where (*) means an optimal solution of the regime CTSW, while (t^*) is the optimal rate of the carbon tax at the CTSW (single social welfare level). Bringing the optimal rate for CTSW tax (t*) return to Stage two, optimal solutions will be:

$$q_1^* = q_2^* = a/(r + 2b + 2g) > 0 \tag{8a}$$

$$\pi_1^* = \pi_2^* = a^2(b + g)/(r + 2b + 2g)^2 > 0 \tag{8b}$$

$$PS^* = 2a^2(b + g)/(r + 2b + 2g)^2 > 0 \tag{8c}$$

$$CS^* = 2a^2(b - r)/(r + 2b + 2g)^2 > 0, \quad When \ b > r \tag{8d}$$

$$T^* = ED^* = 2ga^2/(r + 2b + 2g)^2 > 0 \tag{8e}$$

$$W^* = a^2(3b - r + 2g)/(r + 2b + 2g)^2 > 0, \quad When \ 3b + 2g > r \tag{8f}$$

The variables $q^*, p^*, PS^*, CS^* \ and \ W^*$ are respectively optimal solutions for the firm's output quantity, profits, carbon tax revenue, producer surplus, environmental damage, consumer surplus, and the SWL (social welfare level) at the CTSW regime.

4.2 Carbon Tax at the CTTW

In this regime, our aim of carbon taxation is not just to maximize the SWL but also to tear out environmental damage which is impacted by carbon emissions. The aggregate SWL (social welfare level) of the carbon tax for social welfare factors in consideration to comprehensive consideration of whole social welfare factors which is included producer surplus, consumer surplus, environmental damage and carbon tax revenues. In different words, when maximised social welfare there is no necessity to evict all environmental damage like the carbon tax on the CTSW. Therefore, the objective function of the model's in this regime $W = CS + PS + T - ED$ not subject to $T = ED$. The stage two solution s $q_1 = q_2 = a/(r + 2b + t)$. Take the stage 2 solution into the equation. (6), we have in stage one optimal carbon tax as follows:

$$t^{**} = -b + 2r + 2g > 0 \quad where \ r + g > b/2 \tag{9}$$

Where (**) means the carbon tax regime's optimal solution at the aggregate SWL (social welfare level), while (t^{**}) is the maximal social welfare function second condition. Returning the optimal CTTW tax rate (t^{**}) to the stage two solutions, give the optimal solutions of this regime as follows:

$$q_1^* = q_2^* = a/(r + 2b + 2g) > 0 \tag{10a}$$

$$\pi_1^{**} = \pi_2^{**} = a^2(2r + b + 2g)/(2(3r + b + 2g)^2) \ > 0 \tag{10b}$$

$$PS^{**} = a^2(2r + b + 2g)/(3r + b + 2g)^2 \ > 0 \tag{10c}$$

$$CS^{**} = 2a^2(b-r)/(3r+b+2g)^2 > 0, \quad When\ \ b > r \tag{10d}$$

$$T^{**} = 2a^2(2r-b+2g)/(3r+b+2g)^2 > 0\ \ when\ 2r-b+2g\ \ > 0 \tag{10e}$$

$$ED^{**} = 2ga^2/(3r+b+2g)^2 > 0, \tag{10f}$$

$$W^{**} = a^2/(3r+b+2g) > 0, \tag{10g}$$

q^{**} *is firm's output quantity*, π^{**} *its profit*, PS^{**} *is producer surplus*, CS^{**} *is consumer surplus*, T^{**} *is carbon tax revenue*, ED^{**} *is environmental damage*, *and* W^{**} is social welfare level (SWL) in the CTTW (total social welfare level) regime.

4.3 Equilibrium Comparisons of Social Welfare and Environmental Damage

A difference between a welfare level at optimal in a CTSW regime Equation (8f) and Eq. (10g) is the CTTW regime:

$$W^{**} - W^{*} = a(2r-b)^2/[(3r+b+2g)(r+2b+2g)^2] \geq 0 \tag{11}$$

In equation (11) the optimal SWL (social welfare level) at the CTTW regime should be always greater or equal CTSW regime. This result indicates that when the CTTW regime is adopted by authority, the community necessarily obtains a higher SWL (social welfare level) from the CTSW regime. This finding results in CTTW providing a more comprehensive consideration for enhancing the level of social welfare than CTSW. The former is not eliminate environmental damage only but stimulates producer surplus and consumer surplus however, the latter focuses mainly on eliminating environmental harm.

The difference in tax shift effects for CTTW and CTSW affects the SWL (social welfare level). The proof is the price demand elasticity becomes larger more and more (i.e. parameter b gets smaller more and more), and the difference between W^{**} and W^{*} increases; In different words, the CTTW regime provides a less tax shift impact than the regime CTSW where a great tax shift impact will degrade the SWL. Also in a different way, the regime CTTW creates little social welfare deformity than the regime CTSW. Proof that the regime CTTW creates a bigger social welfare level from the regime CTSW. Based on that, the first proposition is:

Proposition 1

The carbon tax applied on the CTTW is better than a carbon tax applied on the CTSW.

Proof:

This proposition is proved by equation (11) As:

$$W^{**} - W^{*} = [a(2r-b)]^2/[(3r+b+2g)(r+2b+2g)^2] \geq 0$$

For proposal 1, we back to the study by Khastar et al. [29] finds Finland's carbon tax policy reduces carbon emissions same time shows a negative impact on social welfare. Thereafter, they suggest an optimal price of carbon or a future carbon tax regime revision that could be considered. Based on the Equations. (8 & 10) observation, the difference between the environmental damage of both regimes are:

$$ED^{**} - ED^{*} = 2ga^2/(3r + b + 2g)^2 - 2ga^2/(r + 2b + 2g)^2 < 0 \; when \; r > b/2 \qquad (12)$$

In eq. 12, if $b \to 0 \; (i.e \; e_p^d \to \infty) \; than \; ED^{**} < ED^{*}$, which implies the CTTW regime causes little environmental damage than CTSW when the demand price elasticity for a product is large; Conversely, if the $b \to \infty \; (i.e \; e_p^d \to 0)$, then $ED^{**} > ED^{*}$, which means that the CTSW regime causes smaller environmental harm than the CTTW regime when the price elasticity of demand for the product is small.

We next investigate the effect of product substitution on environmental damage and find that when r = 0 (that is, two independent products), $ED^{**} > ED^{*}$, which means that the CTSW regime causes smaller environmental damage than the CTTW regime when substituting the two products is small. On the contrary, if r = 1 (that is, two products are a complete substitution), then $ED^{**} < ED^{*}$, which means the regime CTTW is a benefit of the CTSW regime incurs small environmental damage when the substitution of the two products is large.

Equivalent summary (12) is that the CTTW (CTSW) regime charges a carbon tax on a product with high (low) substitution and that large (small) price elasticity of demand for the product can cause low environmental damage. An interesting finding is that the CTSW regime could use the carbon tax revenues to eliminate all environmental damage, but the environmental damage is not necessarily less than that of the CTTW regime. The reason is that the CTSW regime does not use the tax rate to restrict the company's output; Instead, tax revenue is used to remove all environmental damage. Thus, the quantity of products under the CTSW regime may be higher than those under the CTTW regime. On the contrary, the CTTW regime needs to be concerned with the level of total social welfare, including both sides of the economy and the environment, so that it may restrict the quantity of the product and further limit the environmental harm caused by any by-product in manufacturing to treat. Based on this discussion, we have the following proposition as follows.

Proposition 2

The function of a carbon tax at the individual social welfare level is to eliminate all environmental damage by carbon tax revenue, but the environmental damage of a carbon tax at the single social welfare level is not necessarily less than a carbon tax on the aggregate social welfare level.

Proof

This suggestion can be proven by Eq. (12) Like $ED^{**} - ED^{*} = 2ga^2/(3r + b + 2g)^2 - 2ga^2/(r + 2b + 2g)^2 < 0 \; when \; r > b/2$, Proposition 2 is similarly supported by Pato' et al. [30] who concluded that the CMR would harm the development of the EU energy sector and increase greenhouse gas emissions because the CMR is not an embargo tax regime.

4.4 Social Welfare Equilibrium Comparisons and the Carbon Tax Rate

According to Equations (7) and (9), we find that a carbon tax on a product with high product substitution and high product price elasticity of demand will result in $t^{**} > t^{*}$. In addition, we conclude in Proposition 1 that the level of social welfare in the CTTW regime is always higher than in the CTSW regime. Hence, an interesting finding in the CTTW regime is that a higher tax rate does not necessarily lead to a lower level of social welfare. The result arises because a market that has a high substitution rate and a large elasticity of demand to the product price causes more quantity of the product than that in a market that has a low substitute for the product and a small elasticity of demand to the price of the product; Hence, the higher tax rate in the CTTW regime can restrict the quantity of the product and further reduce environmental damage. In addition, the high tax rate in the CTTW regime also creates a slight distortion in the market and leads to an increase in consumer surplus and producer surplus. Based on the above discussion, we have the third proposition as follows.

Proposition 3

In the carbon tax regime on the total social Welfare level, a high carbon tax rate may cause a high level of social welfare.

Proof

This proposition may be approved with eq. 7 as $t^{*} = 2g$ and eq. 9 as $t^{**} = -b + 2r + 2g > o$, where $r + g > b/2.\; if \; t^{**} > t^{*} \; then \; 2r > b$. Given the result of eq. 11 with $W^{**} - W^{*} = [a(2r - b)]^2/[(3r + b + 2g)(r + 2b + 2g)^2] \geq 0$, if the gap between $t^{**} \; and \; t^{*}$is bigger when $W^{**} \; and \; W^{*}$has big gap also. For Proposal 3, one may refer to Liu et al. [31] who find that a carbon tax can generate comprehensive effects on promoting economic development, reducing carbon emissions, and improving social welfare because a high carbon tax not only accelerates competition in the industrial market but also promotes emissions reduction. Based on the observation of Equations (7) and (9), we also find that the carbon tax rate in a market with low product substitution and small product-price elasticity of demand shows $t^{**} < t^{*}$. Equation (11) further shows that the level of social welfare in the CTTW regime is always higher than in the CTSW regime. This result tells us that a firm in a market with low product substitution and small product-price elasticity of demand will supply a small amount of product to maximize its profits. At this time, the authority that uses a low-carbon tax in the CTTW regime can incentivize the quantity of the product to increase the level of social welfare in this regime; In addition, the low carbon tax rate in this regime has the function of eliminating environmental damage caused by carbon emissions. However, the disadvantage of using CTTW in a market with low product substitution and a small price elasticity of demand is that it may not eliminate all environmental harms.

4.5 NetZero carbon emissions analysis

Since carbon tax revenues are used to evict all the environmental damage meantime the CTSW regime function also to evict all environmental damage, the regime of CTSW must go down the path of NetZero carbon emissions. Also, the function of the regime of CTTW is to expel environmental damage. Therefore, achieving NetZero carbon emissions is possible as a target.

This section examines the NetZero carbon emissions impact by comparing environmental damage from carbon emissions and the tax revenue size of the carbon emission.

The regime of CTSW applies tax revenue on carbon emissions to eliminate all environmental damages, this means $T^{*} - ED^{*} = 0$. Although, the regime of CTTW comprehensively considers maximising the SWL (social welfare level), which also eliminates environmental damage, and at the same time prompts producer surplus and consumer surplus, in which the regime of CTTW doesn't necessarily need to take the NetZero path along carbon emissions. This means the goal of NetZero's carbon emissions in the regime of CTTW may be affected by other factors of the market such as substitution of the product and product demand price elasticity investigated in this paper. E_m^{**} (Carbon Emission Path) in the CTTW regime may be present as:

$$E_m^{**} = T_m^{**} - ED^{**} = a^2(2r - b + 2g)/(3r + b + 2g)^2 - 2ga^2/(3r + 2b + 2g)^2 \geq 0 \ \ When\, r \geq b/2 \quad (13)$$

Equation (13) shows that a CTTW regime may achieve the net-zero carbon emissions target (that is, $T^{**} - ED^{**} = 0$), which is conditional on $r > b/2$. Even carbon tax revenue is a surplus when the CTTW's net zero carbon emissions target (i.e. $T^{**} - ED^{**} > 0$) is met. This is conditional on $r > b/2$ where the product substitution is high and the product price elasticity of demand is large.

According to the result in Eq. (12), the environmental damage in the CTTW regime (ED^{**}) is smaller than the damage in the CTSW regime (ED^{*}) when condition $r > b/2$ is satisfied. This result tells us that when product substitution is high and the price elasticity of demand for the product is large (i.e. $r > b/2$), the CTTW regime achieves Four advantages:

(1) Achieving net zero carbon emissions;

(ii) excess carbon emissions tax revenue;

(3) the environmental damage in the CTTW regime is less than the damage in the CTSW regime;

(4) The level of social welfare is higher in the CTTW regime than in the CTSW regime.

Based on this discussion, we have the following proposition as follows.

Proposition 4

In a market with high product substitution and high elasticity of demand for the product price, a carbon tax regime at the social welfare level can achieve multiple goals, including net-zero carbon emissions, carbon tax revenue surplus, small environmental damage, and high social welfare level.

Proof

Given high product substitution and large product-price elasticity of demand (that is, $2r > b$), then $E_m^{**} = T_m^{**} - ED^{**} = a^2(2r - b + 2g)/(3r + b + 2g)^2 - 2ga^2/(3r + 2b + 2g)^2 \geq 0$ $When\ r \geq b/2$is in the equation. (13) and $W^{**} - W^{*} = a(2r - b)^2/[(3r + b + 2g)(r + 2b + 2g)^2] \geq 0$ in eq. (11) Completed. It includes achievements in net-zero carbon emissions ($E_m^{**} = 0$), surplus carbon tax revenues ($T^{**} < ED^{**}$), small environmental damage ($T^{**} < ED^{**}$), and high social welfare levels ($W^{**} > W^{*}$).

Proposal 4 suggests that an appropriate carbon tax regime conditional on market and product characteristics can achieve multiple objectives. For example, Liu et al. [32] conclude that an effective carbon tax policy can achieve the win-win goal of carbon reduction and GDP growth. When the market offers (r < b/2) (that is, the product substitution is low and the product price elasticity of demand is small), the CTTW regime cannot achieve the goal of net-zero carbon emissions, but the CTSW regime does, and it leads to a decrease in the environmental damage from the CTTW regime; (i.e. $ED^{**} > ED^{*}$). The CTSW regime presents several advantages in the (r < b/2) scenario, but its social welfare level is still lower than that of the CTTW regime. Based on the goals of net carbon emissions, low environmental damage, and high social welfare level, the CTSW regime can achieve the first two goals and the CTTW regime can only achieve the third goal in the (r < b/2) scenario. We summarize the findings in this subsection in the following table in which we compare the effects of CTTW and CTSW regimes on net-zero carbon emissions, environmental damage, and level of social welfare based on product characteristics.

4.6 Carbon Tax Regime and Industrial Transformation

Digital Transactions and Business Transactions are two terms related to industrial transformation. Industrial transformation is the right example of a banking industry that started pushing digital transactions, which are digitising all classical banking services to replace physical banking services with digital services.

Table 1 also presents the process of industrial transformation in such product substitution from high goes to low and the demand price elasticity for the product is from large goes to small at the initial stage of the industrial transformation as the producer differentiates. When the product reaches the mature stage, the product substitution goes high from low meantime the product demand price elasticity goes large from small, which is the last stage in the industrial transformation. Below, figure 1 presents the best regime of the carbon tax at each stage of the industrial transformation with changes in product characteristics.

Table 1. Comparison of the CTSW and CTTW regimes.

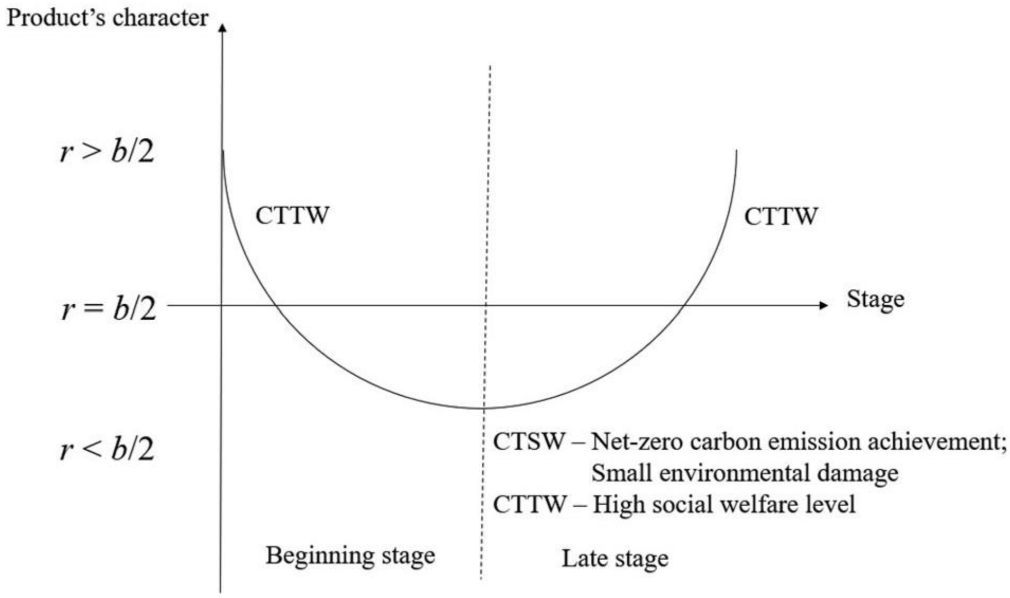
Targets/product's character	Low product substitution small price elasticity of demand	High product substitution large price elasticity of demand
Net-zero carbon emissions	CTSW	CTTW & CTSW
Small environmental damage	CTSW	CTTW
High SWL	CTTW	CTTW

In the initial stage of the industrial transformation with $(r \geq b/2)$, the regime CTTW has the absolute advantage in three goals: achieving the NetZero carbon emission goal, high SWL (social welfare level) and small environmental damage. However, in the start stage of the industrial transformation of $(r < b/2)$, the regime CTSW can achieve the goals of NetZero level of carbon emissions with small environmental damage, also the regime CTTW can achieve a high SWL (level of social welfare).

With the last industrial transformation stage $(r < b/2)$, the regime CTSW has two advantages to achieve zero carbon emissions with small environmental damage, also with the CTTW regime, there is only an advantage over a high level of social welfare (SWL). In the final industrial transformation stage with $(r \geq b/2)$, the regime CTTW offers the absolute advantage for reaching three goals: small environmental zero carbon emissions, damage, and a high level of social welfare.

The authority with no doubt will take on the CTTW regime at the early and last stages of the industrial transformation while product substitution and also demand product price elasticity are significant to achieve three matters. Nevertheless, the authority has the choice to adopt the regime CTSW to achieve the target for NetZero carbon emissions with small environmental damage either/or to choose the regime CTTW to obtain a high SWL in the first and last stages of the industrial transformation while the product substitution with the demand price elasticity are small for the product.

Figure 1. Carbon tax regime at every stage of industrial transformation.



5 The Comparative of the Static Analysis

In this section, we show a comparative static analysis of the SWL and the rate of the carbon tax in relation to product characteristics.

5.1 Carbon Tax Rate and SWL (Social Welfare level)

The previous section concludes the SWL (level of social welfare) in the regime CTTW is constantly higher than in the regime CTSW. However, comparative static analysis at the SWL in the regime CTSW is still necessary when the authority takes NetZero carbon emissions as a target instead of demanding a high SWL (level of social welfare) by adopting a CTSW in the industrial transition phase ($r < b/2$); Any market with the low demand price elasticity and small product substitution. The comparative static analysis of the optimal SWL concerning product substitution and the product demand price elasticity proceeds as follows:

$$\partial W^*/\partial r = a^2(r - 8b - 6g)/(r + 2b + 2g)^3 < 0 \; when \; r < (8b + 6g) \tag{14a}$$

$$\partial W^{**}/\partial r = -3a^2/(3r + b + 2g)^2 < 0 \tag{14b}$$

$$\partial W^*/\partial b = a^2(7r - 6b - 2g)/(r + 2b + 2g)^3 < 0 \; when \; b > (7r - 2g)/6 \tag{14c}$$

$$\partial W^{**}/\partial b = -a^2/(3r + b + 2g)^2 < 0 \tag{14d}$$

Equation (14a) represents the SWL in the regime CTSW increases (decreases) when the substitution of the product is small (large) conditioned by the large produce carbon emission coefficient (g), and Eq. (14b) shows that a change in the SWL in the regime CTTW has the same consequence, but that the magnitude of the carbon emission factor produced does not matter. Equation (14c) present that the level of social welfare (SWL) in the regime CTSW increases (decreases) when the demand price elasticity of the product becomes small (large), which is conditioned by the producer's large carbon emission coefficient. Equation (14d) presents that a change in the SWL in the regime CTTW has also the same consequence, but also it does not matter how large the carbon emission coefficient of the product is. Here we find that the effect of change in the characteristics of the product on changing social welfare in a regime CTSW matters to the product's carbon emission coefficient, which leads to the fact that the goal of the regime CTSW is to eliminate environmental damage which is impulse by carbon emissions. But, the magnitude of the environmental damage is related to the carbon emission factor magnitude of the product. Product substitution and the product demand price elasticity have a relationship where the substitution of the product is low (high) for small (large) demand price elasticity. However, its effect on the SWL is a trade-off effect when the product substitution becomes low (high) to raise (lower) the SWL down (high), the demand price elasticity for the product becomes small (large) and it increases (decreases) the SWL.

This result is reasoned by involving the tax of the carbon emissions in the SWL analysis so that only one factor (for example the product substitution) pushes the SWL, in mean times another factor (the product demand price elasticity) cuts down the SWL after considering the restraint the environmental damage. We present next a comparative analysis of the static of the optimal rate of the carbon tax concerning product substitution and the product demand price elasticity as follows:

$$\partial t^*/\partial r = 0 \tag{15a}$$

$$\partial t^{**}/\partial r = 2 > 0 \tag{15b}$$

$$\partial t^*/\partial b = 0 \tag{15c}$$

$$\frac{\partial t^{**}}{\partial b} = -10 < 0 \tag{15e}$$

Equations (15a) and (15c) show that the optimal carbon tax rate in the CTSW regime is not changed by any economic factor, including product substitution and the price elasticity of demand for the product as discussed in this paper, because the goal of the CTSW regime is to eliminate all Environmental damage caused by carbon emissions. However, the objective of the CTTW regime is to look at the overall social welfare level not only on the ecological level of harm reduction but also on the promotion of consumer surplus and producer surplus. Here, Equations (15b) and (15d) show that if the product substitution or product price elasticity of demand becomes large (small), the optimal carbon tax rate in the CTTW regime rises (falls).

Results in Equations (15b) and (15d) can be explained by large product substitution and the price elasticity of demand causing an increase in the quantity of the product, which also leads to more serious environmental problems. Damage. In order to prevent environmental damage caused by carbon emissions, a high carbon tax rate should be imposed on a per-product basis so that the carbon tax revenue in the CTTW regime cleans up the environmental damage and compensates for the losses of consumer surplus and producer surplus caused by the high carbon tax rate. A high carbon tax rate distorts the production side of the market but corrects the environmental damage side. In addition, higher carbon emission tax revenue offsets distortion in market production, including losses in consumer surplus and producer surplus. On the contrary, the low carbon tax rate is suitable for the market with small product substitution and the price elasticity of demand as the low carbon tax rate can reduce the distortion on the production side by enhancing the quantity of the product and also has the function of eliminating environmental damage.

5.2 Comparative Static Analysis in the Industry)

The first stage of industrial transformation can be described by the substitution of the producer and the product price elasticity of demand becomes small; That is, r becomes small and b becomes large. In the last stage of industrial transformation, product substitution and the product price elasticity of demand are large; That is, parameter r becomes large and parameter b becomes small. In other words, the quantity of the product goes from more to less in the early stage of industrial transformation and then goes from less to more in the late stage of industrial transformation. We arrange the effects of comparative static analysis in the industrial transformation process on the social welfare level and the carbon tax rate in Table 2 and use them to illustrate the changes in the optimal social welfare level and the optimal carbon tax rate during the stages of industrial transformation.

Based on the information in Table 2, we find that the CTSW regime needs to be discussed by classifying into two scenarios, one is the case of small carbon emission factor and the other is the case of large carbon emission factor. Since the goal of the CTSW regime is to eliminate all environmental harm caused by carbon emissions, the carbon emission tax rate does not change regardless of the size of the carbon emission factor and regardless of the early stage or late stage of industrial transition. In the case of a CTSW regime with a small carbon emission factor, product substitution becomes small (large) at the beginning (late) stage of industrial transformation which makes the welfare level decrease (increase), but product price elasticity of demand becomes small (large) at this stage which makes welfare Social increases (decreases). Hence, the net change at the welfare level is uncertain in this case. In the case of the CTSW regime with a high carbon emission factor, product substitution becomes small (large) at the beginning (late) stage of industrial transformation leading to an increase (decrease) in the level of social welfare, and the price elasticity of demand for the product becoming small (large) at this stage leads to a decrease in the level of welfare (increases). Thus, the net change at the welfare level is also uncertain in this scenario.

With respect to the CTTW system, Table 2 tells us that the carbon tax rate becomes low (high) in the early (late) stage of industrial transition as product substitution and product-price elasticity of demand become small (large). On the other hand, product substitution becomes small (large) at the beginning (late) stage of industrial transformation leading to an increase (decrease) in the level of social welfare. However, the price elasticity of demand for a product becoming small (large) at this stage of industrial transformation leads to a decrease (increase) in the level of welfare. Thus, the net change at the welfare level is uncertain in the CTTW system.

From the analysis in this section, we summarise some key findings as follows. First, the CTSW carbon tax rate does not change with changing product characteristics because its goal is to eliminate all environmental harm. Second, the carbon tax rate in a CTTW regime decreases (rises) in the early (late) stage of industrial transformation where product substitution and the product price elasticity of demand are both small (large). Third, regardless of the CTSW and CTTW systems, There is an inverse effect on the enhancement of the welfare level whereby a change in product substitution enhances (lowers) the welfare level, and a change in the price elasticity of demand for the product reduces (enhances) the welfare level. This result indicates that the carbon emission tax rate considers not only increasing the quantity of the product but also reducing the environmental damage in order to maintain an optimal social welfare level.

Table 2: Changes in the optimal social welfare and optimal carbon tax rate during the process of industrialisation.

Regime / industrial	transformation	Beginning stage (r↓ and b↑)	Late stage (r↑ and b↓)
CTSW	Low carbon emissions coefficient (g is small)	$(\partial t^*)/\partial r = 0 \Rightarrow r\downarrow;$ $t^* - (\partial t^*)/\partial b = 0 \Rightarrow b\uparrow;$ $t^* - (\Delta t^* = 0)$ $(\partial W^*)/\partial r > 0 \Rightarrow r\downarrow; W^*\downarrow$ $(\partial W^*)/\partial b > 0 \Rightarrow b\uparrow; W^*\uparrow$ $(\Delta W^*?)$	
	High carbon emissions coefficient (g is large)	$(\partial t^*)/\partial r = 0 \Rightarrow r\downarrow;$ $t^* - (\partial t^*)/\partial b = 0 \Rightarrow b\uparrow;$ $t^* - (\Delta t^* = 0)$ $(\partial W^*)/\partial r < 0 \Rightarrow r\downarrow; W^*\uparrow$ $(\partial W^*)/\partial b < 0 \Rightarrow b\uparrow; W^*\downarrow$ $(\Delta W^*?)$	
CTTW		$(\partial t^{**})/\partial r > 0 \Rightarrow r\downarrow;$ $t^{**}\downarrow (\partial t^{**})/\partial b < 0 \Rightarrow b\uparrow;$ $t^{**}\downarrow -(\Delta t^* < 0)$ $(\partial W^{**})/\partial r < 0 \Rightarrow r\downarrow; W^{**}\uparrow$ $(\partial W^{**})/\partial b < 0 \Rightarrow b\uparrow; W^{**}\downarrow$ $(\Delta W^{**}?)$	$(\partial t^{**})/\partial r > 0 \Rightarrow r\uparrow;$ $t^{**}\uparrow (\partial t^{**})/\partial b < 0 \Rightarrow b\downarrow;$ $t^{**}\uparrow -(\Delta t^* > 0)$ $(\partial W^{**})/\partial r < 0 \Rightarrow r\uparrow; W^{**}\downarrow$ $(\partial W^{**})/\partial b < 0 \Rightarrow b\downarrow; W^{**}\uparrow$ $(\Delta W^{**}?)$

6 Conclusion

Net-zero carbon emissions are the best way to combat global warming and climate change, and an effective carbon tax regime can help achieve its goal. This study examines the carbon tax regime from two points of view: the first is a carbon tax at the single social welfare level, and the other is a carbon tax at the overall social welfare level. The former maximizes the level of social welfare, but is subject to the elimination of all environmental damage caused by carbon emissions, while the latter increases the level of social welfare and eliminates the environmental harm at the same time. In more detail, the common goal of the two carbon tax systems is to maximize the level of social welfare, but the former is conditional on eliminating all carbon emissions, while the latter does not necessarily eliminate all carbon emissions. The individual social welfare carbon tax regime in this study refers to the EU carbon limit adjustment mechanism, which takes net zero carbon emissions as the target. We study the carbon limit adjustment mechanism regime in this study and find its advantages and disadvantages.

Based on the investigation, we summarize the results as follows. (i) A carbon tax taking into account macroeconomic factors can create a high level of social welfare. (2) Even if the carbon tax function recovers all environmental damage using carbon tax revenues, this carbon tax regime cannot guarantee that the smallest environmental damage will be caused. (iii) A high tax rate on carbon emissions does not necessarily lead to a lower level of social welfare when the carbon tax takes into account the level of social welfare comprehensively. (4) In a market with high product substitution and high elasticity of demand to product price, a carbon tax with a comprehensive consideration on the social level not only achieves the goal of net zero emissions but also receives high social welfare. Based on the above findings, it appears that the EU Carbon Limits Adjustment Mechanism has scope to reconsider the way it is implemented. After all, we find that this regime works the opposite in Overland and Sabyrbekov [33].

The industrial transformation causes some changes in economic factors. In general, product substitution and price elasticity of demand become small in the early stage of industrial transformation in which the product is in the stage of product differentiation and become large in the late stage of industrial transformation in which the product has entered the stage of maturity. Our study concludes that regardless of the onset or late stage of industrial transformation, and regardless of any carbon taxation system, changes in product substitution or product price elasticity of demand have a trade-off effect on changing the level of social welfare, which leads to an uncertain change in the level of social welfare. Social Welfare. This result means that the authority can use a suitable carbon tax regime to remove environmental damage caused by carbon emissions, stimulate consumer demand and benefit businesses at the same time. Hence, the authority must consider the industrial and market characteristics to adopt an appropriate carbon tax system.

Zero net carbon emissions and a maximum level of social welfare are the goals of the relevant authority. We summarize three outcomes of the carbon emissions tax as follows.

(i) Regardless of product substitution or product price elasticity of demand, a carbon tax at a single social welfare level can achieve the goal of net zero carbon emissions, but it cannot maximize a social welfare level.
(ii) A carbon tax at the aggregate social welfare level can simultaneously achieve net zero carbon emissions targeting and maximization of the social welfare level, provided that the market has high product substitution and high elasticity of demand to the price of the product.
(iii) Considering the low product substitution and the small product price elasticity of demand, the authority either chooses a carbon tax regime at the aggregate social

welfare level to maximize the social welfare level, but sacrifices the goal of net zero carbon emissions, or chooses a carbon tax regime at the individual social welfare level to achieve the goal net carbon emissions, but it cannot maximize the level of social welfare.

One administrative implication from this point is that there must be different mechanisms for carbon tax regimes to be adopted by the authority under different market types.

This study establishes the framework under a subgame Nash perfect equilibrium and a dynamic game with complete information. Referring to Gibbons [34], full information means all the information in the game, including the possible strategy, the timing of the player's action and the bonuses as general knowledge. In other words, all the variables in the game are known so that the government can determine the optimal CO2 emission tax rate, and the company can also determine the optimal strategy based on the government's policy and the actions of its competition. However, a game with uncertain variables is another research avenue that can indicate a game with incomplete information. Moreover, different from game theory analysis where we use partial equilibrium analysis to discuss industrial transformation, the computerized general equilibrium (CGE) model can investigate the impact on all macroeconomic markets, including the capital market, labour market, and foreign exchange market, and almost. The study of the carbon event through the CGE approach appears in the work of Zhou et al. [35], Lin and Jia [36], Liu et al. [9], and Jia et al. [37]. The complete information constructions and partial balance analysis in this study are research limitations, but we can replace them with incomplete information and general balance analysis in a future study.

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